Radio-optical identification of very-steep spectrum radio sources from the UTR-2 catalogue

Heinz Andernach
Depto. de Astronomía, Univ. de Guanajuato, Guanajuato, Mexico
Oleg V. Verkhodanov
Special Astrophysical Observatory, Nizhnij Arkhyz, Russia
Natalia V. Verkhodanova
Special Astrophysical Observatory, Nizhnij Arkhyz, Russia

Abstract

We used radio source catalogues accessible from the CATS database (http://cats.sao.ru) to establish radio continuum spectra for decametric radio sources in the UTR-2 catalogue (Braude et al. 1978–1994). From these, we select a sample of 23 sources with ultra steep radio spectra ($\alpha \leq -1.2$, $S \sim \nu^{\alpha}$) and present accurate positions and sizes from FIRST and NVSS. The search for optical counterparts from the APM (object) and DSS (image) databases, as well as infrared and X–ray identifications of these UTR sources are in progress.

1 Introduction

A radio survey obtained with the UTR telescope (Kharkov, Ukraine) at frequencies 10–25 MHz has resulted in a catalog of 1822 sources (Braude et al. 1978–1994; `www.ira.kharkov.ua/UTR2`). Covering about 30% of the sky north of $-13°$ declination, this survey is presently the lowest-frequency source catalog of its size, and thus provides an ideal basis to study the little known optical identification content of sources selected at decametric frequencies. In the original version of the UTR-2 catalog (UTR in what follows) there is no radio identification at other frequencies for 7% of the sources, and for 81% there is no optical identification. Our goal is to identify all UTR sources with known radio sources and to search for optical counterparts on the Digitzed Sky Surveys.

Here we present our first results on a subsample of ultra-steep spectrum (USS) sources (spectral index $\alpha \leq -1.2$, $S \sim \nu^{\alpha}$). This class of sources is being actively studied by various groups (Parijskij et al. 1996; Röttgering et al. 1997; McCarthy et al. 1997), mainly because they are often identified with very distant radio galaxies, which are probes of the early Universe and thought to be indicators of proto-clusters (e.g. Djorgovski 1987).

2 Radio identification

The rather large uncertainties of UTR positions ($\sim 0.7°$) require an iterative process for finding radio counterparts at successively higher frequencies (and thus higher positional accuracy).

In this we aided ourselves by selecting previously cataloged sources from the CATS database (Verkhodanov et al. 1997a) in a box of RA×DEC = $40'\times40'$ centred on the nominal UTR position. The "raw" spectra given by these fluxes were refined using computer charts of source locations around UTR positions. All counterparts from TXS, GB6 and PMN within circles of $1'$ radius were considered one source. Groups of sources lying further apart were assigned separate spectra, each with the UTR flux as upper limit.

We were able to fit spectra for all but 7 of the 2314 radio counterparts to UTR sources. Fits were either straight (S), convex (C^-), or concave (C^+) curves in the $\lg\nu$–$\lg S$ plot (see also Verkhodanov et al. 1997b, 1998). The resulting catalog includes information from a large number of electronically available catalogs of radio, infrared, optical and X–ray sources. The distribution of radio source spectra among the various spectral types is given in Table 1, and Fig. 1 shows the spectral index distribution of sources at high and low Galactic latitudes.

Table 1: Distribution of radio continuum spectral types of 2307 radio counterparts to UTR sources, where X=$\log_{10}$(frequency/MHz), and Y=$\log_{10}$(flux density in Jy)

Spectral class	Fitting function	N	%
Straight (S)	$Y = +A + B * X$	894	39
Convex (C^+)	$Y = +A \pm B * X - C * X^2$	184	8
Concave (C^-)	$Y = +A - B * X + C * X^2$	1150	50
or	$Y = \pm A \pm B * X + C * EXP(-X)$	79	3

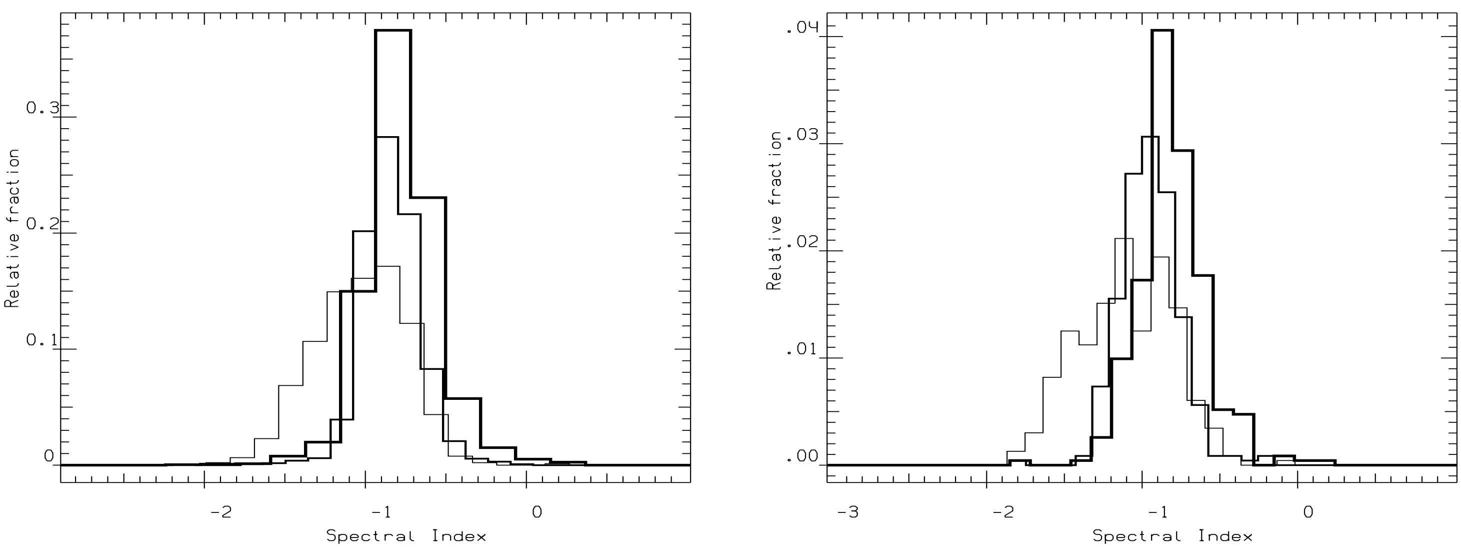

Figure 1: Distributions of spectral indices of 2307 radio counterparts to 2314 UTR sources, fitted at frequencies 80 (thin line), 365 and 1400 MHz (bold line). Left: 2004 high Galactic latitude sources ($|b| > 10°$); right: 303 sources at low Galactic latitudes ($|b| < 10°$).

Table 2: The 38 FIRST counterparts to 23 USS sources ($\alpha \leq -1.2$) from the UTR catalog. We list the UTR name, the size of the source complex (or deconvolved size if a single component) from NVSS and FIRST, respectively, the FIRST RA & Dec, the peak and integrated component flux at 1.4 GHz from FIRST, their deconvolved major and minor axes, and major axis position angle (N through E) from FIRST.

UTR name (B1950)	NVSS size (")	FIRST size (")	RA (J2000) Dec	S_p (mJy)	S_i (mJy)	Maj ($''$)	Min ($''$)	PA (°)
GR0002+00 b	16.	7.4	000650.56+003648.4	47.6	75.9	7.4	1.1	154
GR0135−08	28.	20.	013714.87−091155.4	5.2	44.3	30.8	7.5	98
			013715.08−091203.3	10.2	36.9	15.6	4.3	90
			013715.45−091155.8	8.2	25.7	13.0	5.4	148
			013716.22−091149.5	10.0	39.3	11.3	9.3	119
GR0257−08 a	<18.	4.5	025919.15−074501.2	162.5	211.9	4.5	1.3	59
GR0257−08 b	80.	83.	030040.22−075302.2	18.4	52.8	15.6	3.0	174
			030040.56−075259.6	10.1	122.8	30.7	13.1	163
			030042.99−075413.8	7.0	34.2	16.2	8.4	32
			030042.99−075358.0	13.6	47.8	12.3	7.4	152
			030043.60−075418.3	6.4	22.0	11.2	7.6	75
			030043.75−075407.2	6.6	22.4	15.6	4.8	170
GR0723+48 b	47.	3.1	072651.18+474041.5	23.8	29.1	3.1	2.0	175
			072655.00+474051.0	51.8	75.7	5.6	1.1	85
GR0818+18	24.	22.	082032.48+192731.3	31.1	49.2	6.1	1.7	174
			082032.73+192709.0	76.4	98.5	3.9	1.6	8
GR0858−02 b	70.	55.	085935.06−015842.1	11.7	27.2	10.2	3.2	122
			085936.10−015851.8	9.8	15.9	6.2	2.8	128
			085938.21−015908.1	20.2	43.6	8.1	4.5	133
GR0910+48	36.	29.	091359.00+482738.0	26.9	88.6	11.6	5.2	100
			091401.83+482729.2	39.6	110.2	10.9	3.9	106
GR0922+42 b	<19.	2.7	092559.66+420335.3	199.7	244.1	2.7	2.4	98
GR0942+54	14.	8.	094618.12+543003.8	51.1	57.1	2.5	0.9	36
			094618.53+543010.1	75.3	80.6	1.7	1.1	16
GR1149+42	<17.	5.0	115213.58+415344.9	83.7	115.4	5.0	1.0	18
GR1214−03	<17.	3.2	121755.30−033722.0	176.9	208.9	3.2	1.2	111
GR1223−00	25.	25.	122722.97−000813.8	5.8	13.6	8.4	5.0	100
			122724.54−000821.1	8.4	16.9	7.1	4.6	116
GR1243+04	<18.	6.8	124538.38+032320.1	249.4	379.9	6.8	1.3	158
GR1318+54	25.	23.	132202.81+545758.1	30.3	90.3	9.5	5.9	82
			132205.33+545805.3	8.6	35.9	10.7	8.6	55
GR1320+43	<19.	3.3	132232.32+425726.5	129.3	154.6	3.3	1.0	81
GR1355+01 c	<19.	10.	135821.64+011442.0	77.0	88.4	2.9	1.4	42
			135822.08+011449.4	169.9	180.9	1.6	1.3	32
GR1447+57	<19.	4.5	144630.04+565146.8	75.2	99.2	4.5	0.7	148
GR1527+51 b	<19.	1.4	152828.36+513401.4	203.9	212.8	1.4	0.8	140
GR1539+53 b	<18.	6.4	154144.69+525054.5	87.0	136.7	6.4	0.8	66
GR1613+49	<19.	3.0	161631.16+491908.2	56.1	66.2	3.0	1.3	10
GR1731+43	42.	40.	173333.87+434318.6	32.9	57.9	6.3	3.0	164
			173334.26+434300.8	22.8	27.3	3.1	1.5	173
			173334.41+434251.4	12.3	15.8	3.3	2.4	159
			173334.58+434239.8	27.3	51.0	7.5	2.3	150
GR2211−08 b	<19.	8.6	221519.65−090005.8	75.2	125.0	8.6	1.4	176

3 Subsample of ultra-steep spectrum sources

In our catalog of 2314 radio counterparts (the full list will be published in a forthcoming paper) there are 422 S-type sources with "very-steep spectrum" (VSS), and for the present work we selected from these a subsample of 102 "ultra-steep spectrum" (USS) objects ($\alpha \leq -1.2$). To further increase the radio-positional accuracy, we searched for radio counterparts of USS sources in the February (1998) version of the FIRST catalog (White et al. 1997), resulting in 38 FIRST counterparts for 23 UTR sources (see Table 2). If a UTR source has more than one acceptable counterpart in FIRST, we label these components with letters a, b, c, etc. Only one of the FIRST components (labeled GR1527+51 b) is truly unresolved by the FIRST beam of $\sim 5''$ (i.e. has a major and minor axis of $< 2''$), while all other objects have a multi-component or extended structure. We checked the sources also in the lower resolution NVSS at 1.4 GHz (Condon et al. 1998). Usually, the larger the source complex, the larger the NVSS/FIRST flux ratio. Radio spectra of some of the source complexes are shown in Fig. 2. Examples of two FIRST maps of multi-component objects GR0910+48 and GR0942+54 overlaid on DSS-2 images are shown in Fig. 3. According to the NASA Extragalactic Database (NED), the complex source GR0135−08 is identified with the $z = 0.041$ galaxy MCG-02-05-020, GR1214−03 is an LCRS QSO at z=0.184, and GR1243+04 is a radio galaxy (4C+03.24) at z=3.57. Our investigation of DSS-2 images for the unidentified sources is in progress.

Acknowledgements We wish to thank A.P. Miroshnichenko and D. Krivitskij of Institute of Radio Astronomy (Kharkov) for providing data and for useful discussion. The co-creators of the CATS database Sergei Trushkin and Vladimir Chernenkov (SAO RAS) provided useful comments.

References

[1] Braude S.Ya., Megn A.V., Rashkovski S.L., Ryabov B.P., et al. 1978, Ap&SS 54, 37

[2] Braude S.Ya., Megn A.V., Sokolov K.P., et al. 1979, Ap&SS 64, 73

[3] Braude S.Ya., Miroshnichenko A.P., Sokolov K.P., Sharykin N.K. 1981, Ap&SS 74, 409

[4] Braude S.Ya., Sharykin N.K., Sokolov K.P., Zakharenko S.M. 1985, Ap&SS 111, 1

[5] Braude S.Ya., Sokolov K.P., Zakharenko S.M. 1994, Ap&SS 213, 1

[6] Condon J.J., Cotton W.D., Greisen E.W., Yin Q.F., Perley R.A. et al. 1998, AJ 115, 1693

[7] Djorgovski S., 1987, in *Nearly Normal Galaxies*, ed. S. Faber (Springer-Verlag), p. 290

[8] McCarthy P.J., Miley G.K., De Koff S., Baum S.A., et al. 1997, ApJS, 112, 415

[9] Parijskij Yu. N., Goss W.M., Kopylov A.I., Soboleva N.S., et al. 1996, Bull. SAO, 40, 5

[10] Röttgering H.J.A., van Ojik R., Miley G.K., et al. 1997, A&A 326, 505

[11] Verkhodanov O.V., Trushkin S.A., Andernach H., Chernenkov V.N. 1997a, eds. G. Hunt & H.E. Payne. ASP Conf. Ser. 125, 322

[12] Verkhodanov O.V., Andernach H., Verkhodanova N.V. 1997b, in *Problems of modern radio astronomy* (in Russian), Institute of Applied Astronomy of RAS. V. 1, p. 330–331.

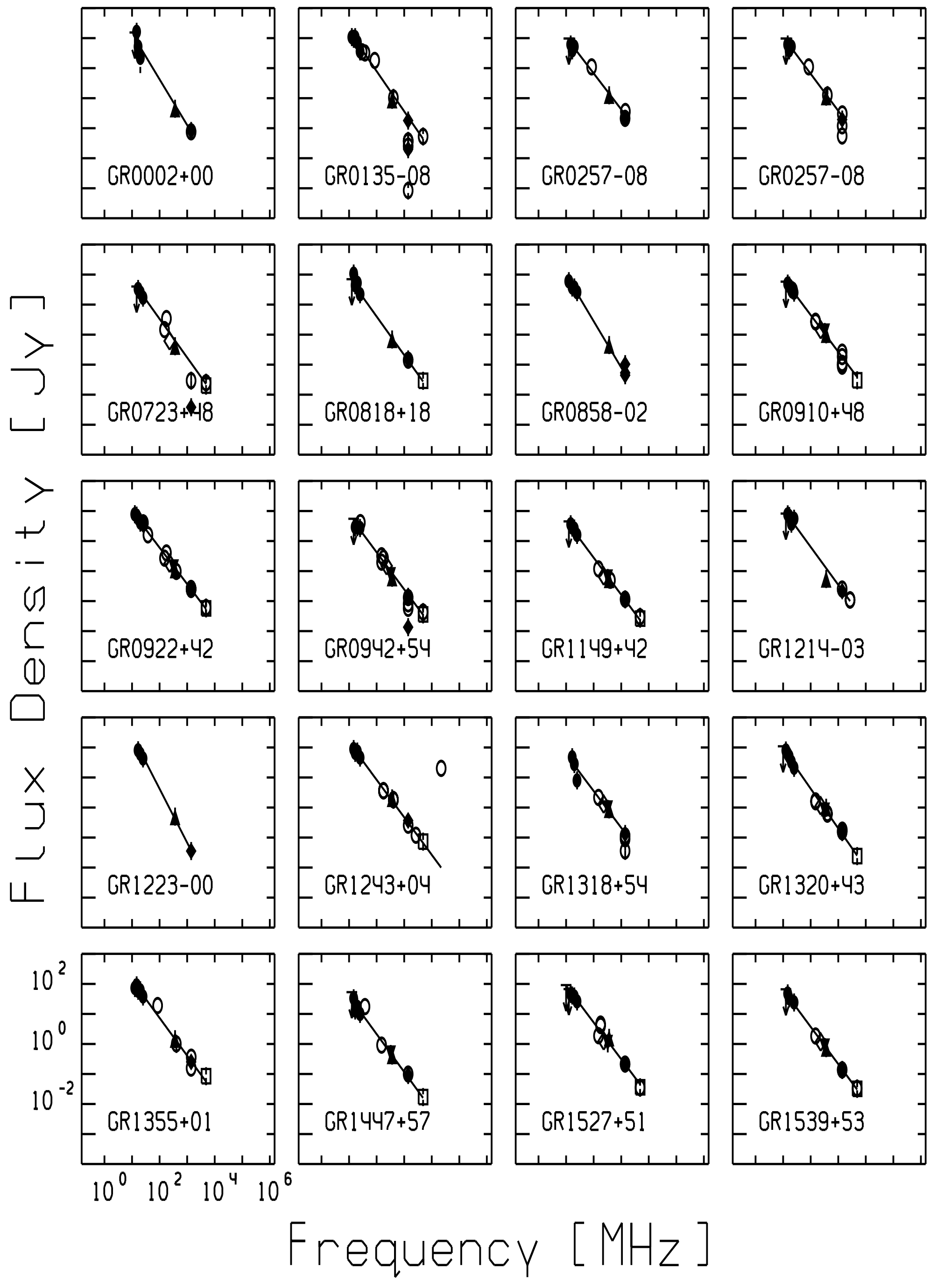

Figure 2: Radio spectra of 20 USS sources from UTR, identified with FIRST sources.

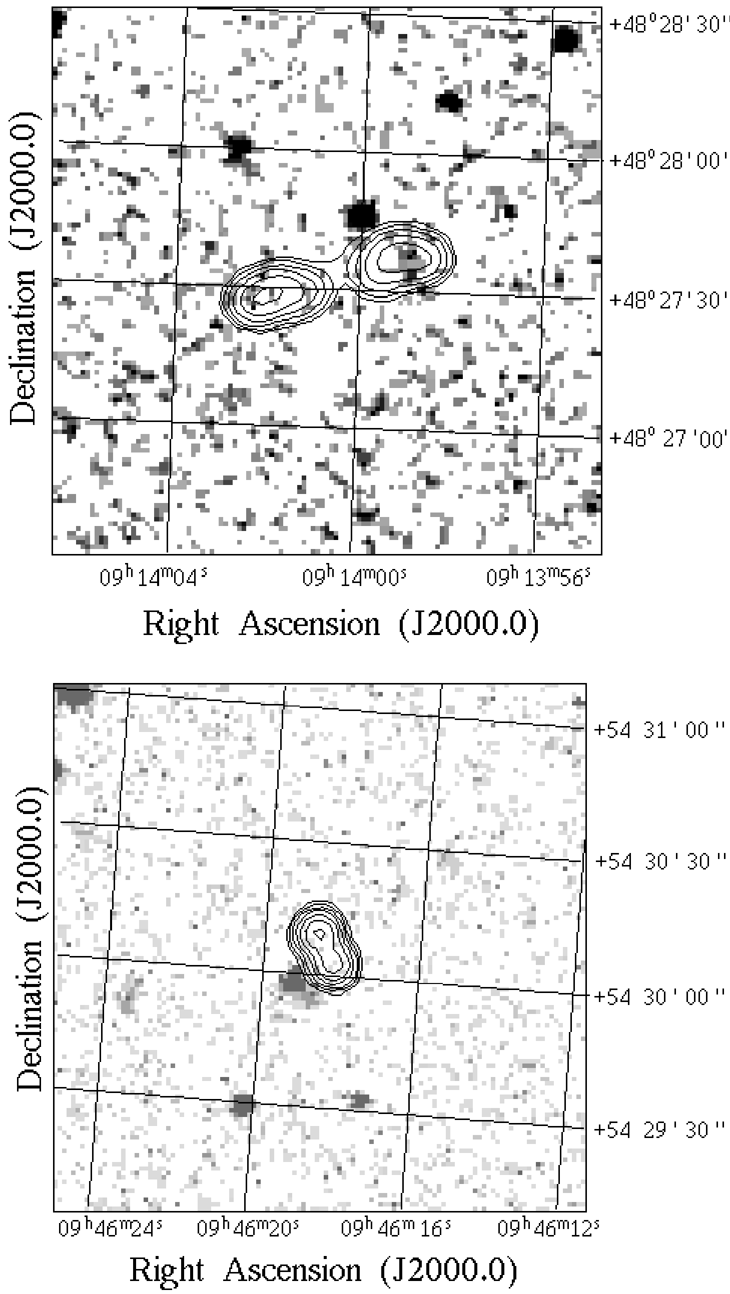

Figure 3: Examples of two FIRST maps of multicomponent objects GR0910+48 (upper panel) and GR0942+54 (lower panel) overlaid on DSS-2 images. There are no optical counterparts above the plate limit at the symmetry center of these radio doubles.

[13] Verkhodanov O., Andernach H., Verkhodanova N.V., Loiseau N., 1998, in *Observational Cosmology with the New Radio Surveys*, eds. M.Bremer, N.Jackson & I.Pérez-Fournon, Kluwer Acad. Publ. ASSL 226, p. 255–256.

[14] White R.L., Becker R.H., Helfand D.J., & Gregg M.D. 1997, ApJ 475, 479 (see `http://sundog.stsci.edu/first/catalogs.html`)